Application of simulation based digital twin technology to real-time monitoring of complex engineering structures

SBN Asset Management Day

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May 25th 2021

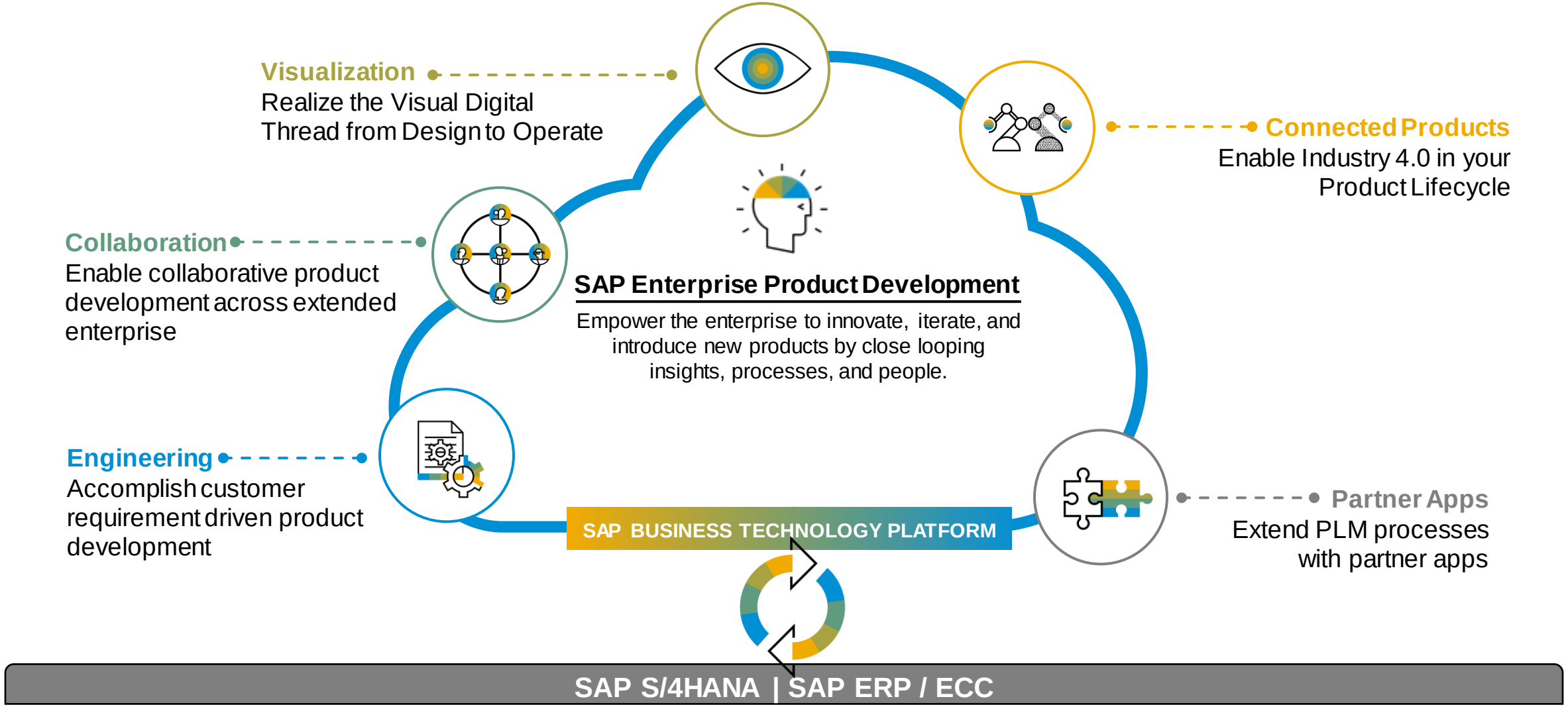
THE BEST RUN SAP

Agenda

- Introduction to Enterprise Product Development (EPD) for Connected Products
- Fish farm monitoring for Havfarm
- Bridge monitoring for Norwegian Public Roads Administration

SAP Enterprise Product Development

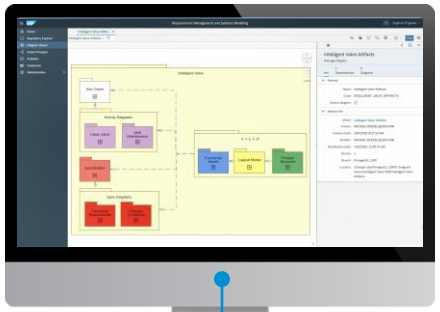
Reimagine Innovation



SAP Enterprise Product Development

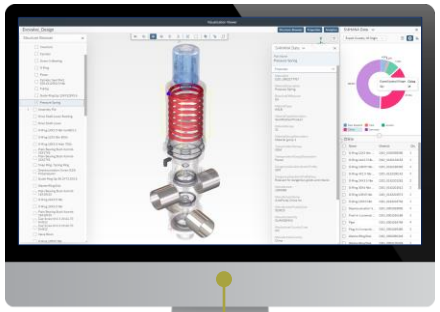
Capabilities and Key Features

Engineering



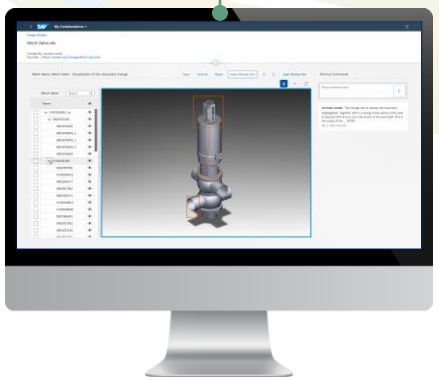
- Requirements Acquisition
- Requirements Management
- Functional Structure Management
- Impact & Lineage Analysis
- Test Planning & Execution
- Manage Test Artefacts & Results

Visualization



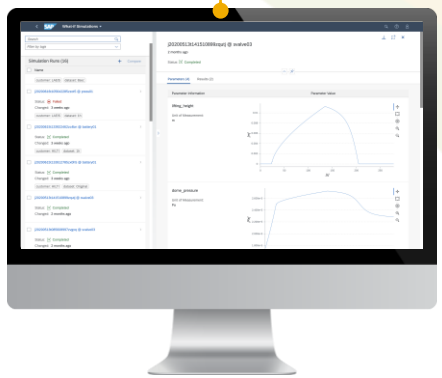
- Simplified User Experience
- Import, Browse & Share
- Visual Data Integration
- Author, Edit & Enhance Visualizations
- Role-based Visual Application Templates
- 3D Visual Work Instructions

- Requirements Driven Engineering Collaboration
- Share Documents
- 3D Visual Design & Redlining
- Simple Task/Workflow Management
- Collaborate on Structured Product Data incl BoM
- Supplier Collaboration
- Collaborate on Changes
- Comments



Collaboration

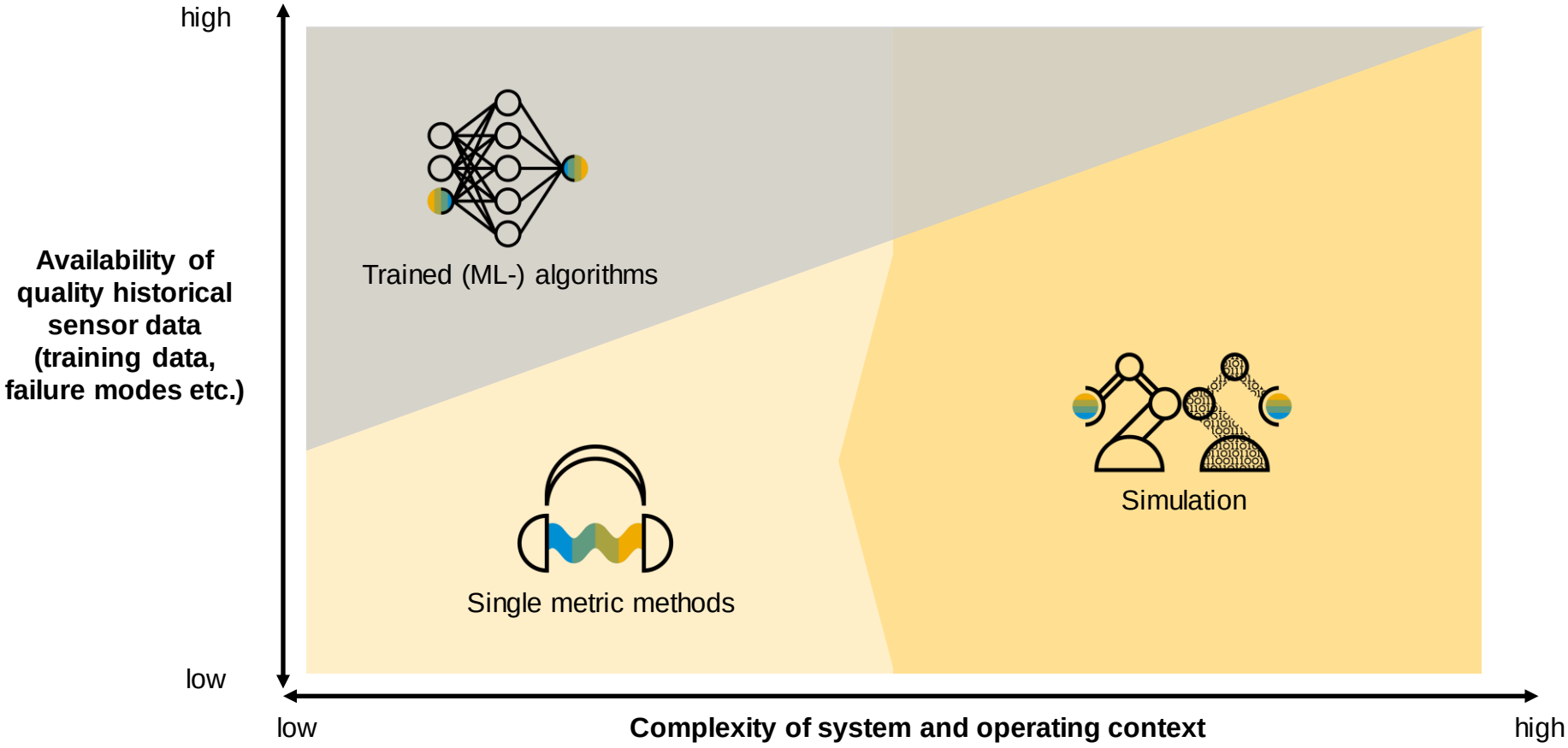
- Simulation Based Digital Twin
- Virtual Sensors
- Performance and Health Prediction
- Run What-If Simulations
- Dynamic 3D Visualization
- Integration with Intelligent Asset Management
- Integration of ANSYS Digital Twin simulations
- Integration of OpenModelica system simulations



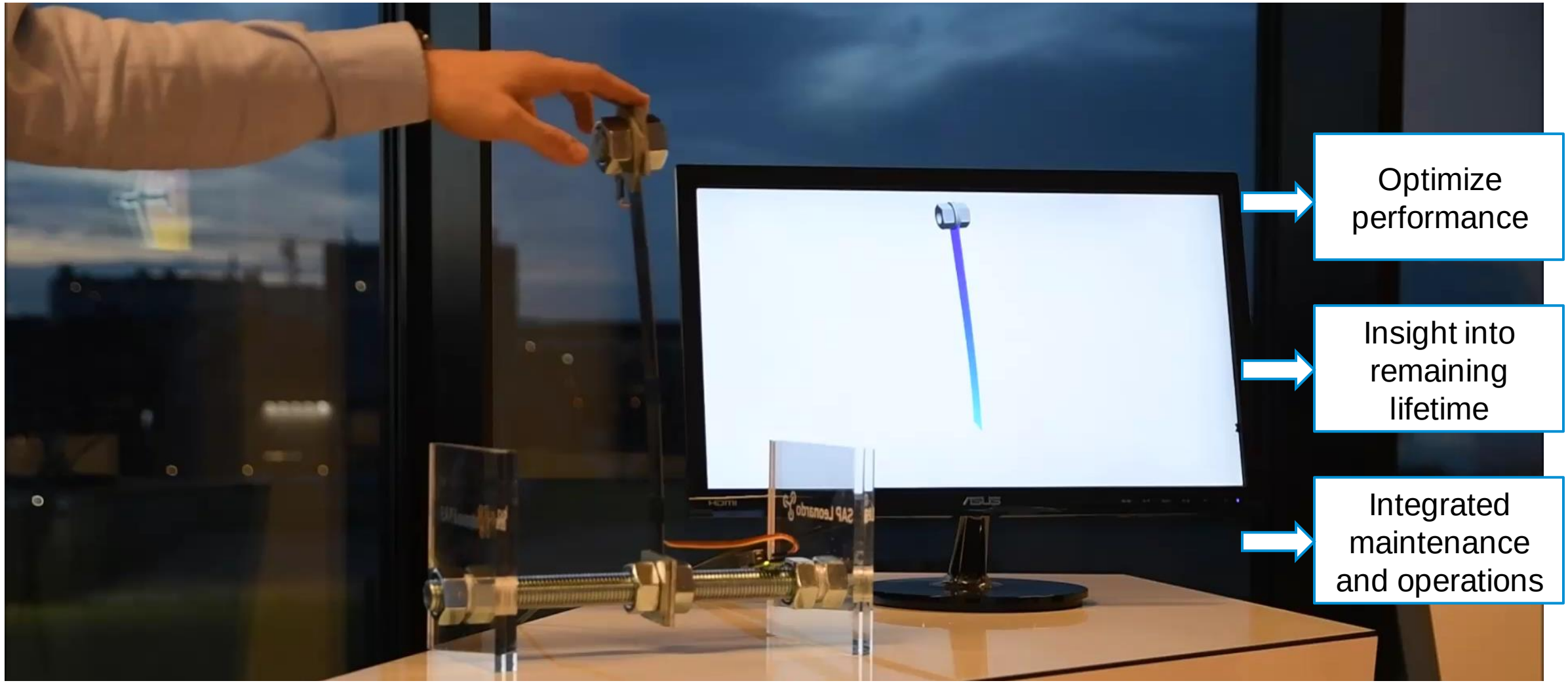
Connected Products

Intelligent Technologies to determine asset behavior based on sensor data

Trained algorithms and physics models have different strengths

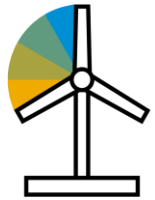


Our mission is to accurately describe the behavior and the actual condition of the system or equipment directly in the IT solution

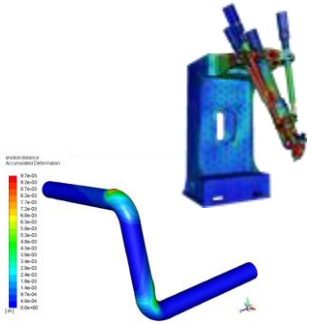


And enable companies to create Connected Products based on IoT-enabled engineering models for better asset design, health predictions and operations

OEM centric



Operator centric

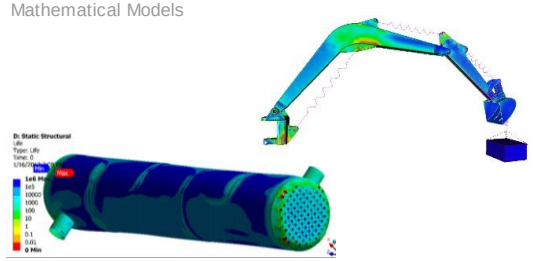


- Reuse of **engineering models** from R&D phase
- Establish a **digital thread** to enable prescriptive maintenance services via virtual sensors

Reduced-Order Models
In-house tools
Systems
Optical
Finite Element Analysis

Engineering

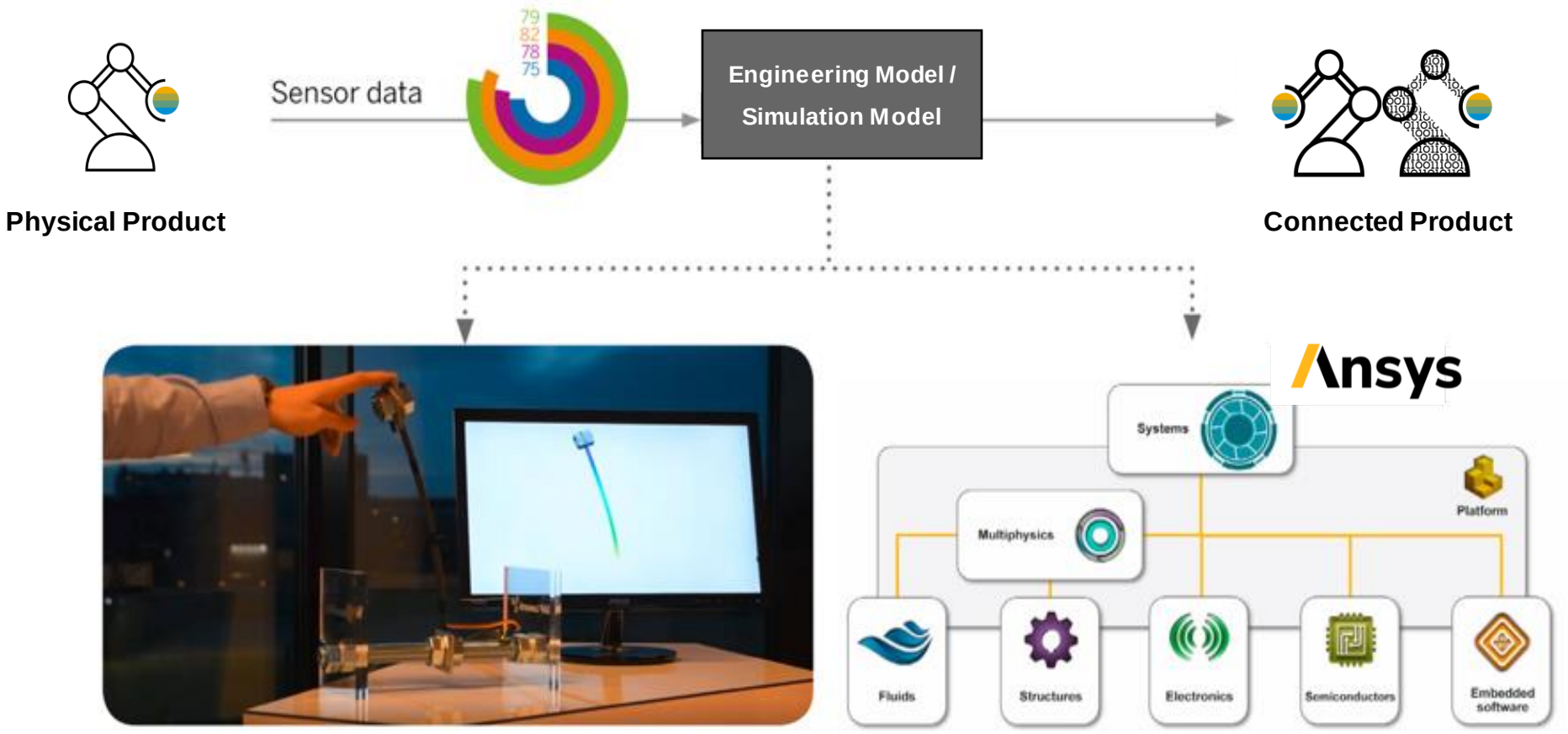
Computational Fluid Dynamics
Electromagnetics
Mathematical Models



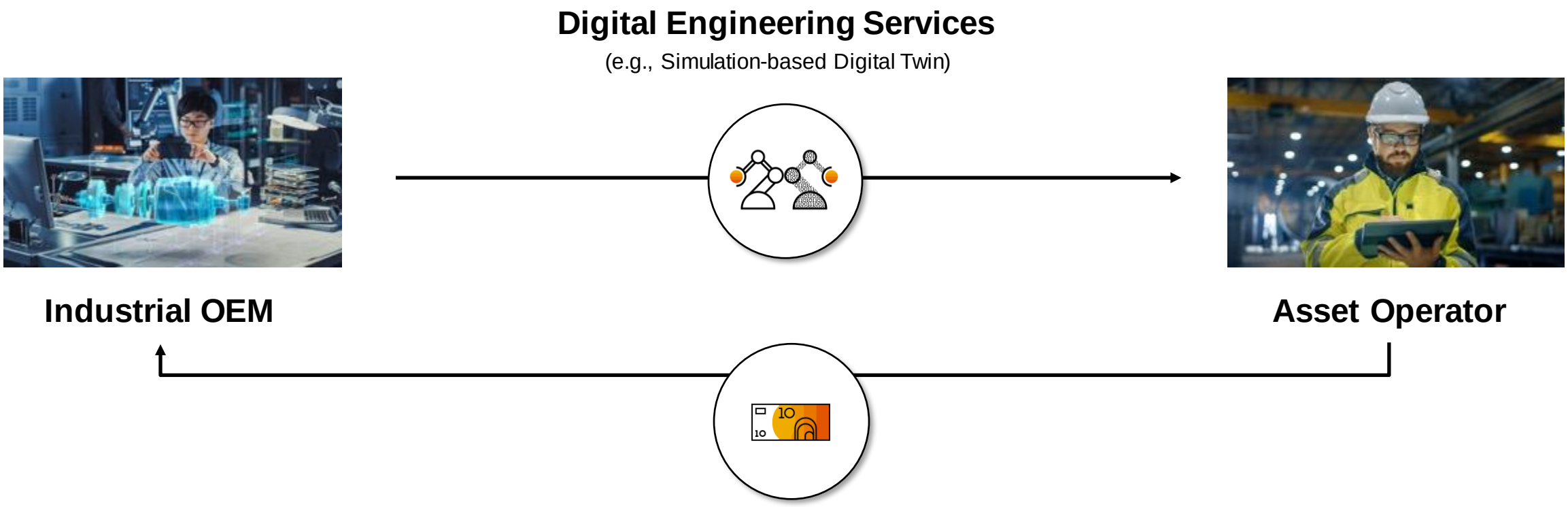
Value added Digital Services based on IoT-enabled Engineering Models

- Optimize performance
- Insight into remaining lifetime
- Integrated maintenance and operations

SAP and ANSYS teamed up to embed engineering runtimes in SAP EPD for a wide range of physical domains



Industrial product OEM's can use SAP EPD to create new revenue streams based on the models. Operators can use them in Asset Management.



SAP Enterprise Product Development for Connected Products is a SaaS application for simulation-based Digital Twins

Key Features in Connected Products

Internet of Things

Use data from sensors to close the engineering loop. Understand how products are operated.

Simulation-based Digital Twins

Combine IoT data with engineering simulations from ANSYS, Modelica and other tools supporting the FMU standard

Product Health Prediction

Establish an early warning system for product related health and performance issues

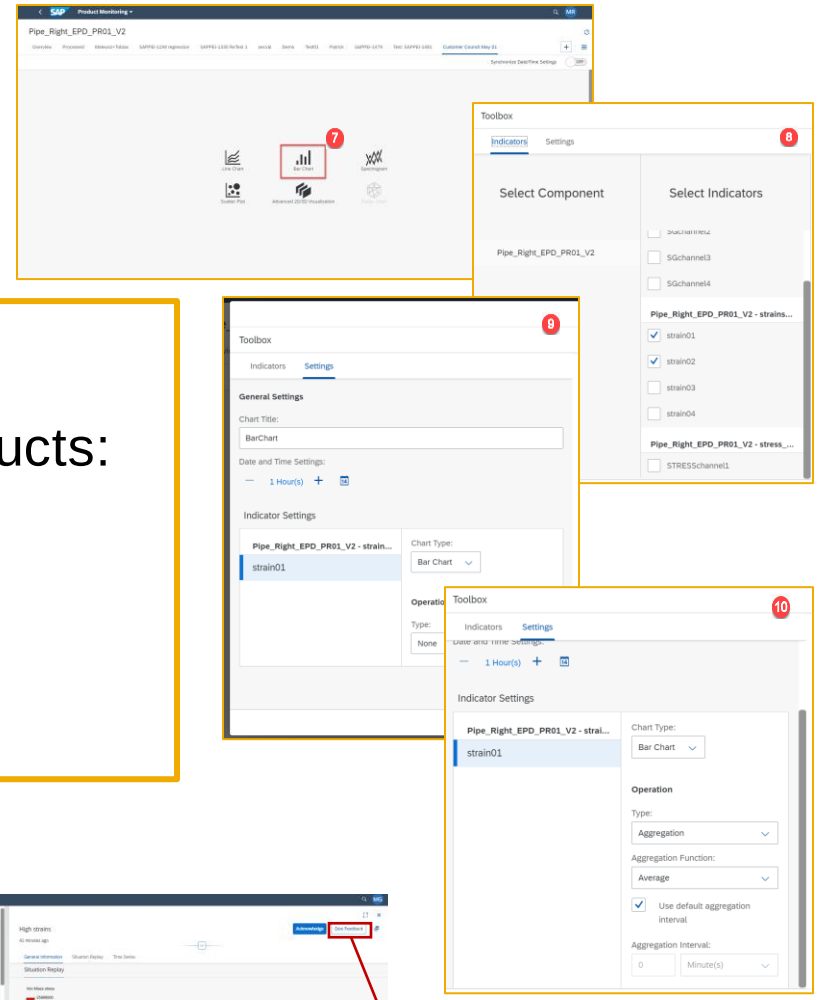
Monetize new Digital Engineering Services

Create new revenue channels by selling engineering insights as a service.

Integration with Intelligent Asset Management

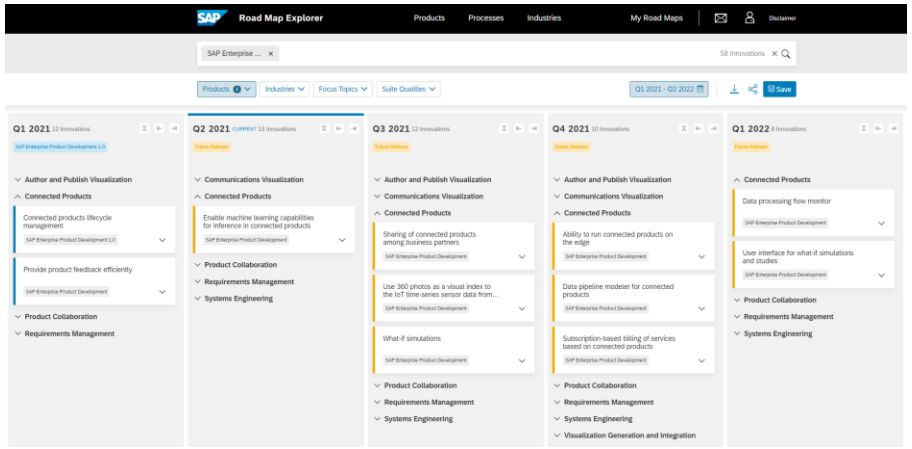
Leverage Connected Product Templates in asset management for advanced predictive maintenance.

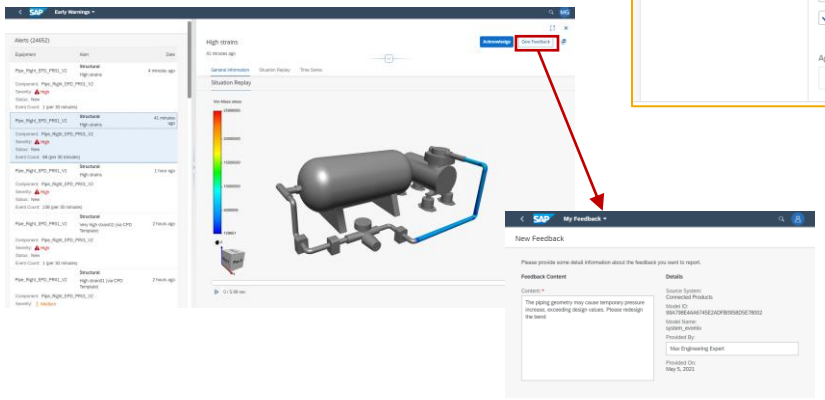
More details at SBN PLM Webinar:



SAP Enterprise Product Development (EPD) for Connected Products: Enabling Industry 4.0 for the Product Lifecycle

May 28, 10:30-11:30





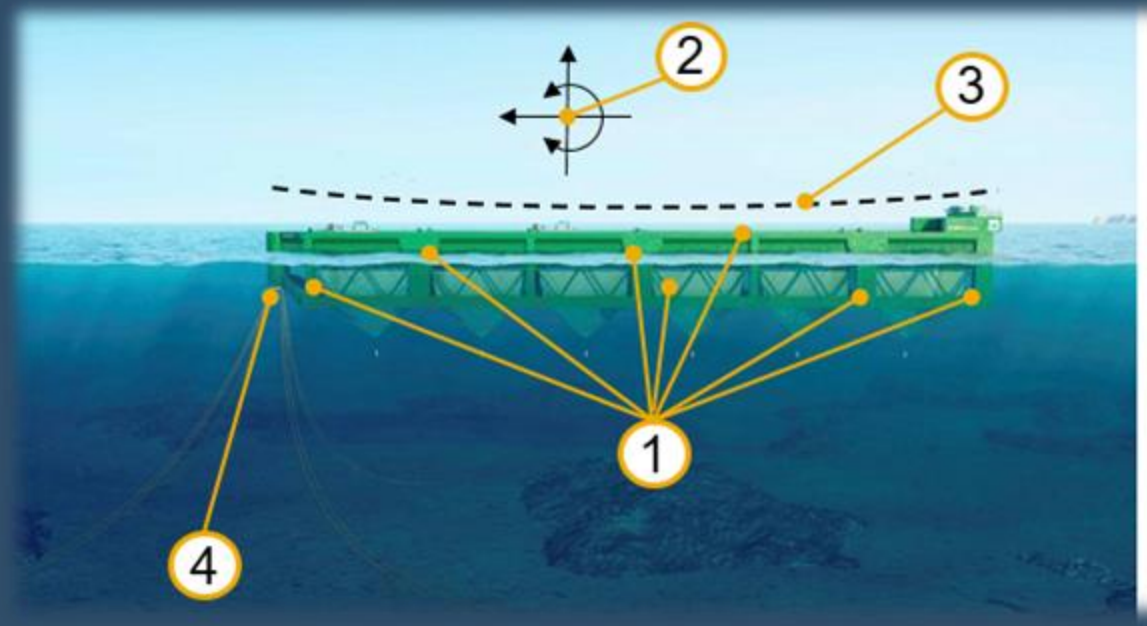
Fish farm monitoring for Havfarm

Havfarm; Facts & Figures

- Capacity: 10 000 tons live salmon
- Steel weight: ~30 000 tons
- Main dimensions: Length 385m, Width 59.5m, Draught 30,7m
- Stationary anchored outside Melbu, Connected to on-shore power grid and network through fiber connection

Connected Sensors & Systems

- Structural monitoring: 8 sensors
- Mooring Line monitoring: 11 sensors
- Feed Release Monitoring: Reads data from feeding sys.
- Weather parameters: Connected to system with wave radars.



Primary functionality

1) Structural monitoring of critical areas

2) Logging global vessel movements

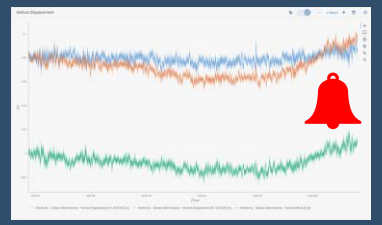
3) Logging global deformations due to ballasting

4) Moring line monitoring (Angles)

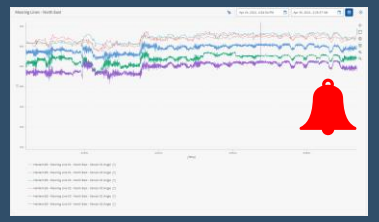
Benefits of the Hull Monitoring System

- Estimate structural «usage» in areas of low Accessibility. Support Maintenance planning. Verification of design basis.
- Gives knowledge of actual response to sea-states. Input to berthing operations.
- Large global deformations may increase the need for maintenance and/or decrease service life. Knowing the ballasted state gives important information and enables ballast optimization.
- Knowing if chain has snapped, or indication of dragging.

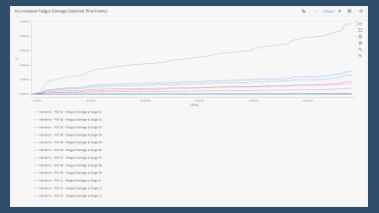
Structural Monitoring



Vessel Deformations

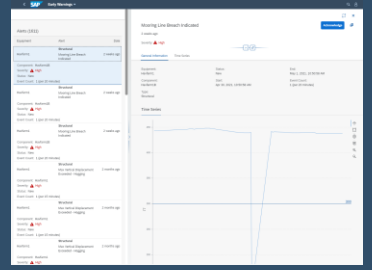


Moring Line Monitoring



Fatigue Damage in POIs

Alerting



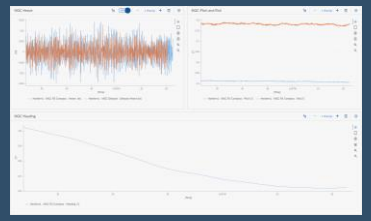
Notifications & Alerting

Diagnosis

Diagnostics on Primary sensors

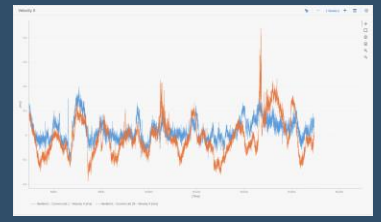
(Structural Monitoring)

Vessel Response and Environmental Conditions

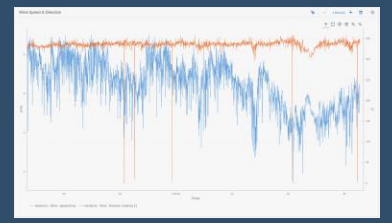


Vessel Motions

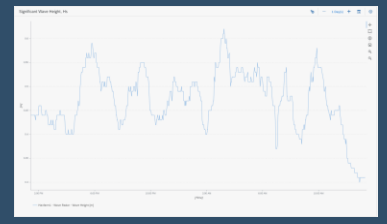
Pitch, Roll, Heave, Heading



Current Measurments

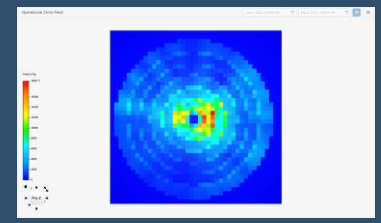


Atmospheric Measurements



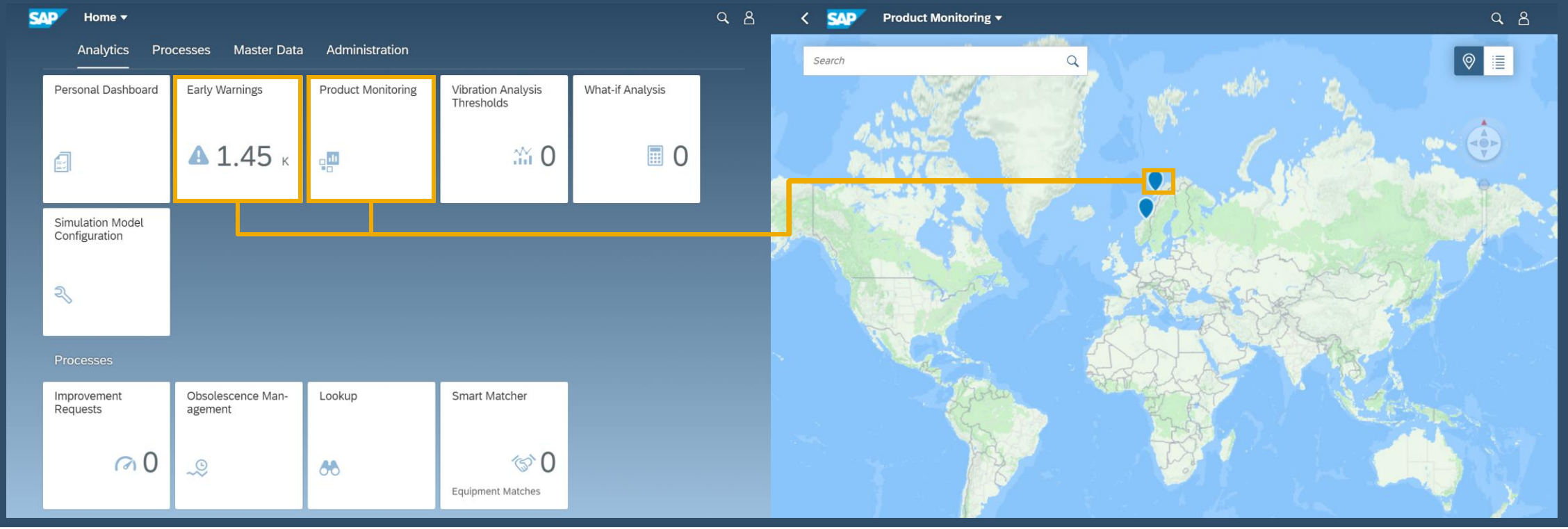
Wave Statistics, Draught

Government Reports



Feed Released in sea within operational area

Application Overview Havfarm Monitoring System



Peek into the User Interface

Product Functionality:

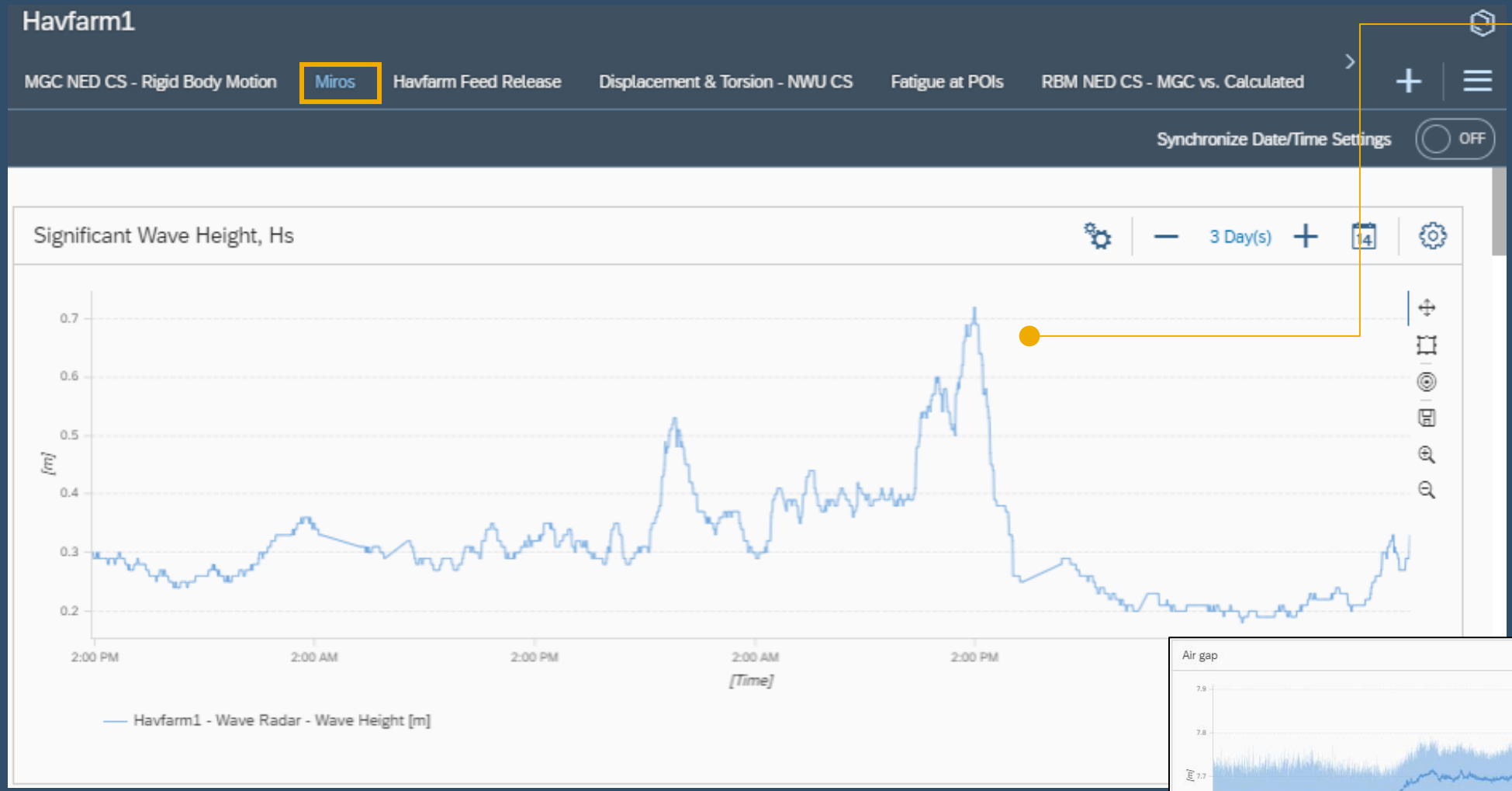
- Monitoring of environmental parameters:
- Global Vessel Movements
- Structural monitoring:
  - Fatigue in Points of Interest
  - Structural Deformations
- Monitoring of Feed released into the sea surface
- Alerting

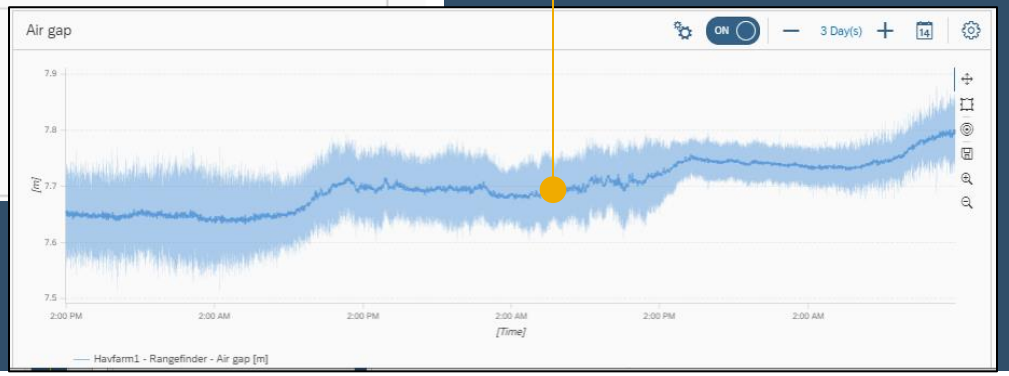
Capabilities Utilized

Showing data from radar system
Showing data from sensors

Digital Twin; FE-model Output
Data processing and Thresholds + Alerting
Data gathering and processing

Environmental Parameters – What's the weather like?

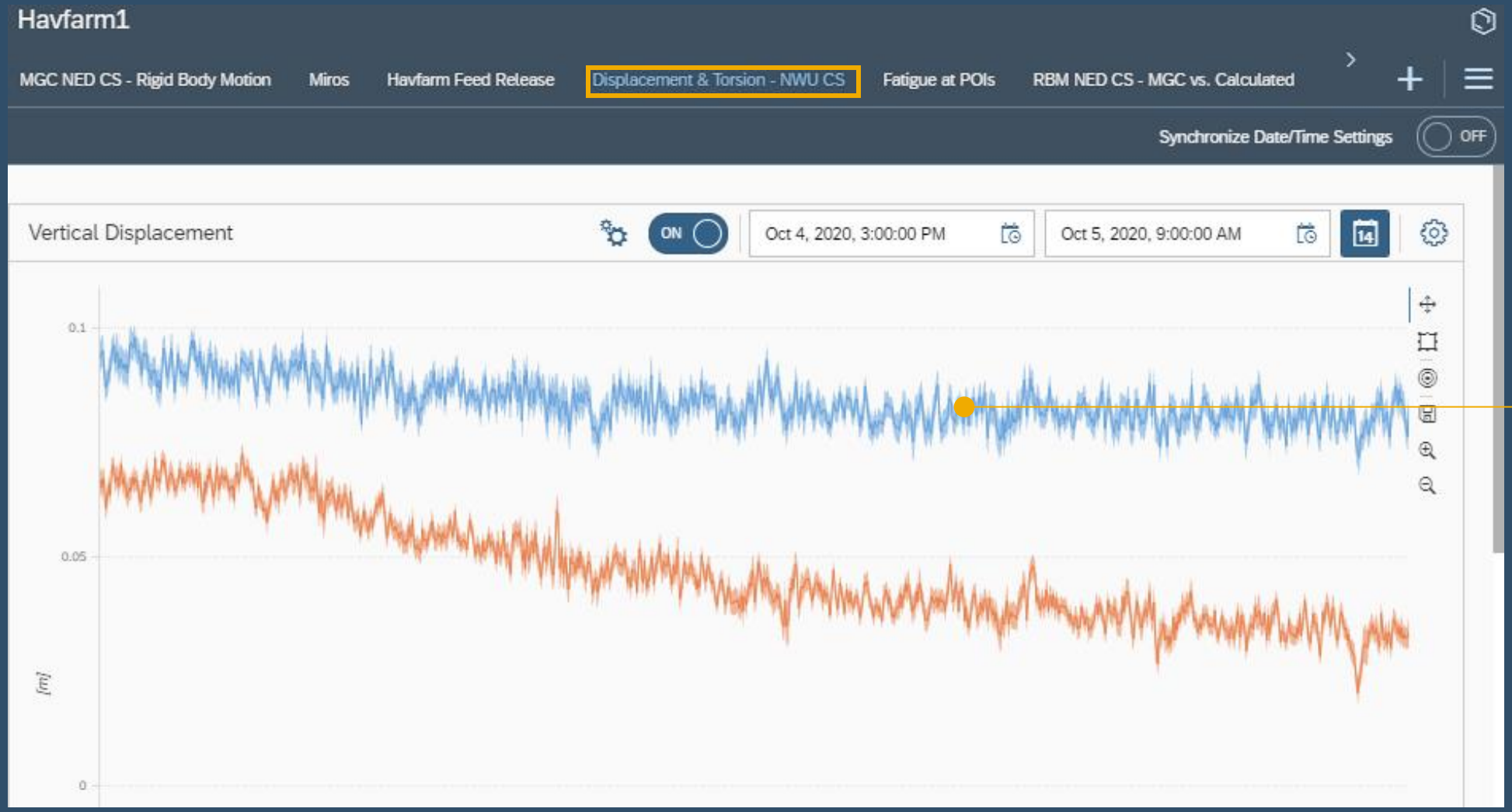




- Wave Height
- Current Direction
- Current Speed
- Draught
- Air Gap
- Wave Direction
- Wave Period

Global Vessel Movements – Vessel Response to environment

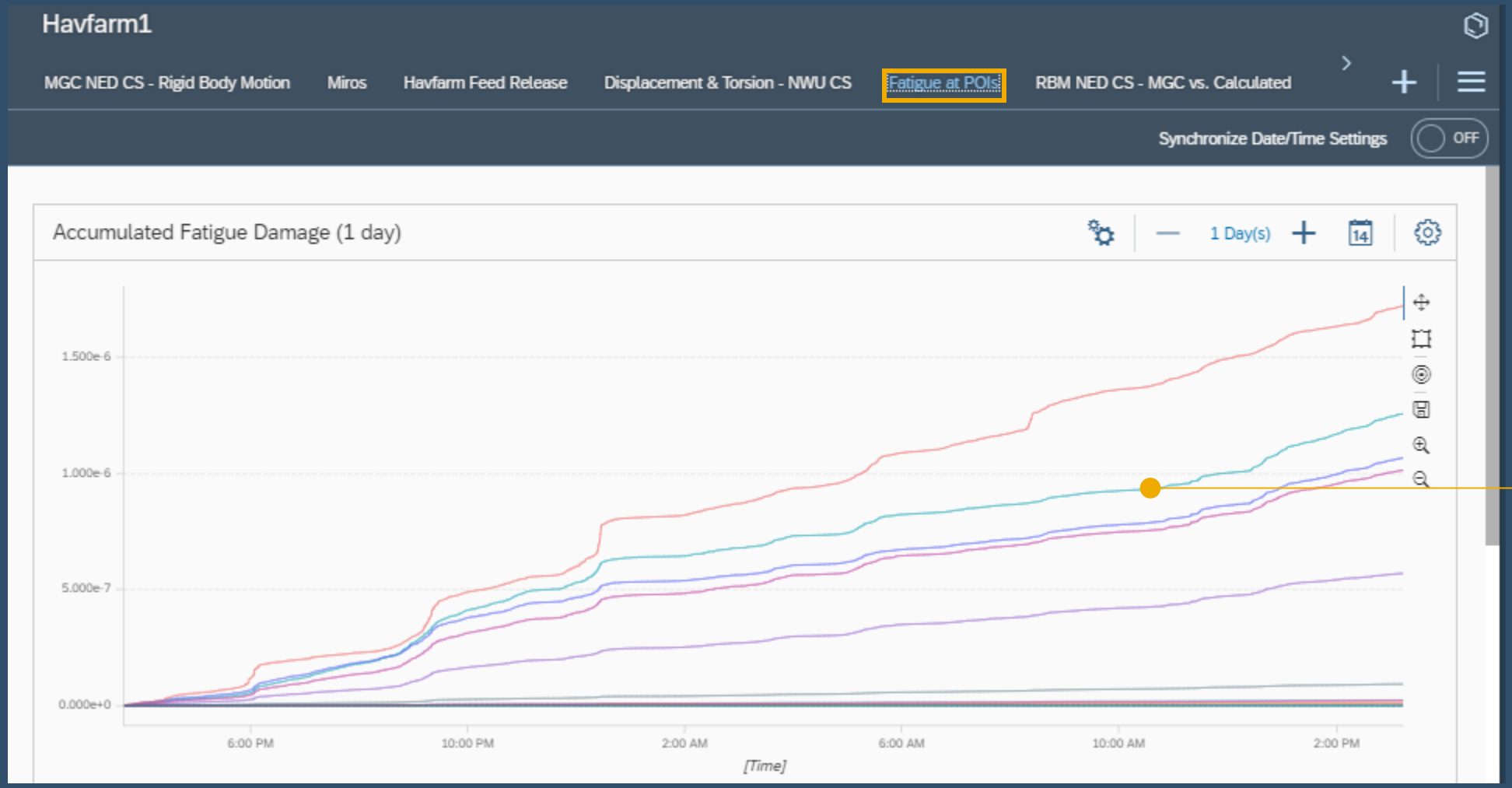
Structural Monitoring – Structural Deformations



Deformations in structure;

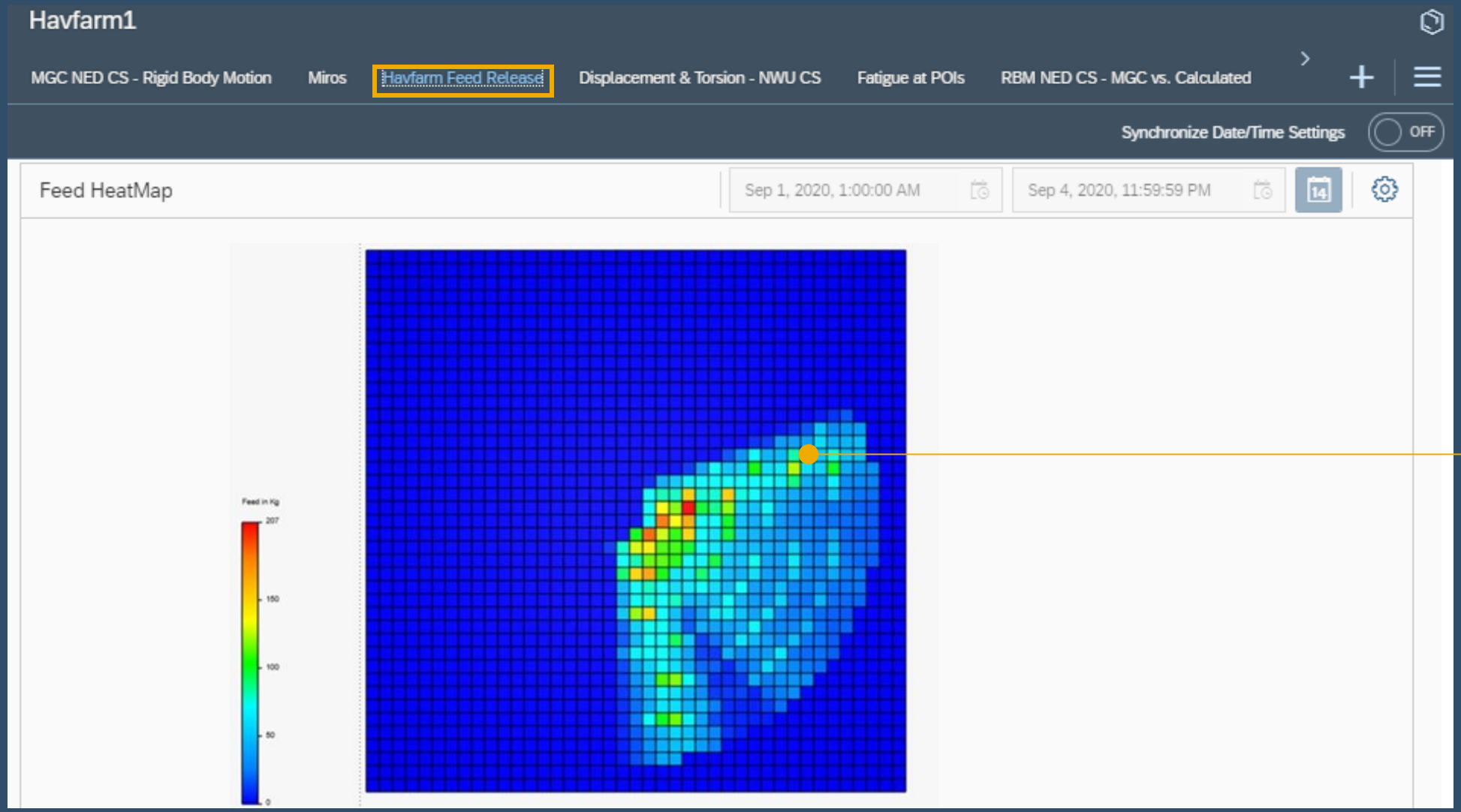
- Are they Critical?
- Is re-ballasting a good idea?

Structural Monitoring – Fatigue Monitoring



Structural “Usage” in Locations of special Interest

Feed Release Monitoring – Government Reports



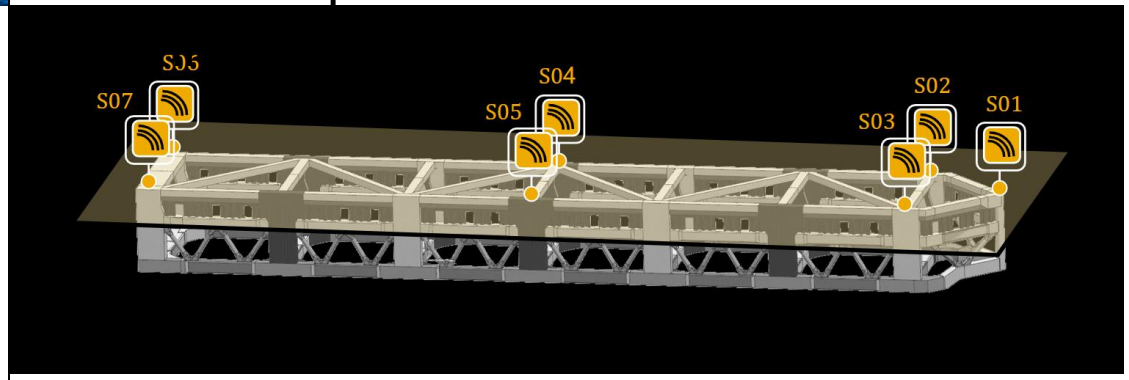
Knowing how much Feed that has been released into the Sea within Havfarms area of operation.

Nordlaks – Havfarm 1 HMS How it works, high level

Actual → **Digital (Cloud)**

- Sensors logging physical movements
- Hub for data logging (Edge Client)
  - Receiver (sensor data)
  - Transmitter (sensor data sent to Cloud)

- System for Data Reception & Storage
- System for Processing of Data
  - With algorithms
  - Use data to actuate FE-models
  - Use data with system simulations
- Show processed Results or Raw Data



Insights ← **Data**

Nordlaks – Havfarm 1 HMS "Hows" on Structural monitoring

Knowing where in structure to Focus

- **Risk Based Inspection (RBI) program**

Sensors on structure

- **To capture structural response**

Re-use of Engineering models (Sesam FE-models)

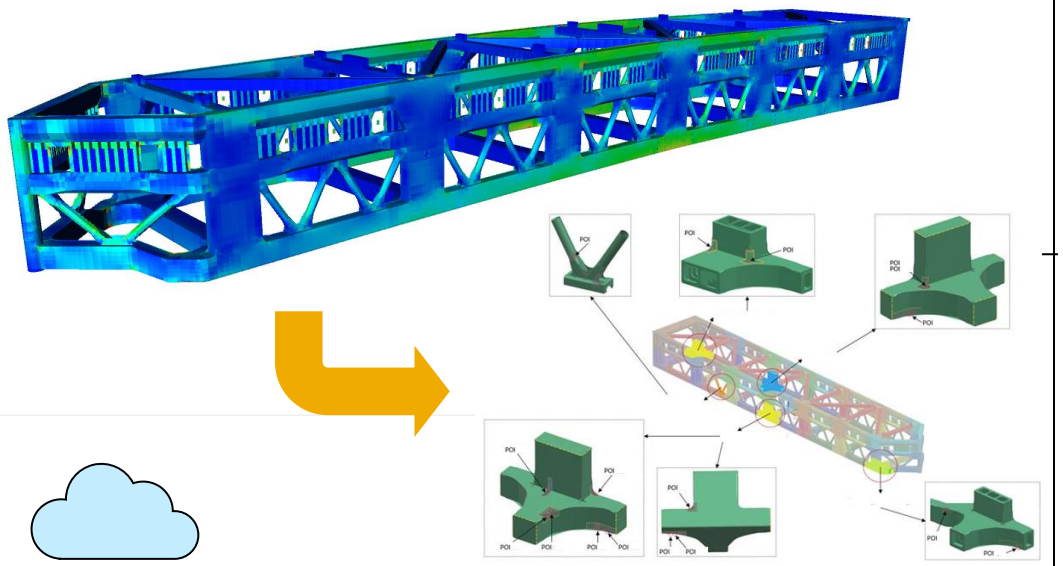
- **To build digital representation of physical structure**

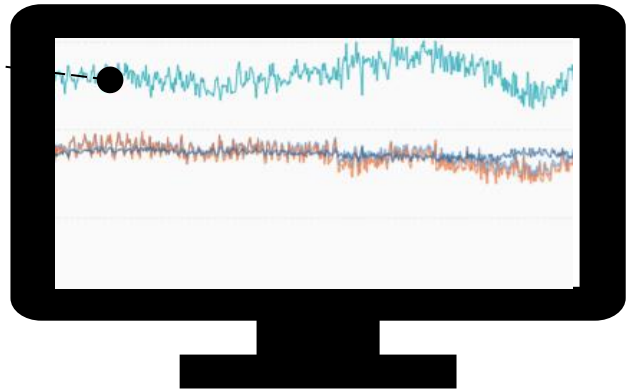
Realtime simulations with input from physical data

- **To get insight into "structural usage" - Fatigue damage at Points of Interest in structure.**

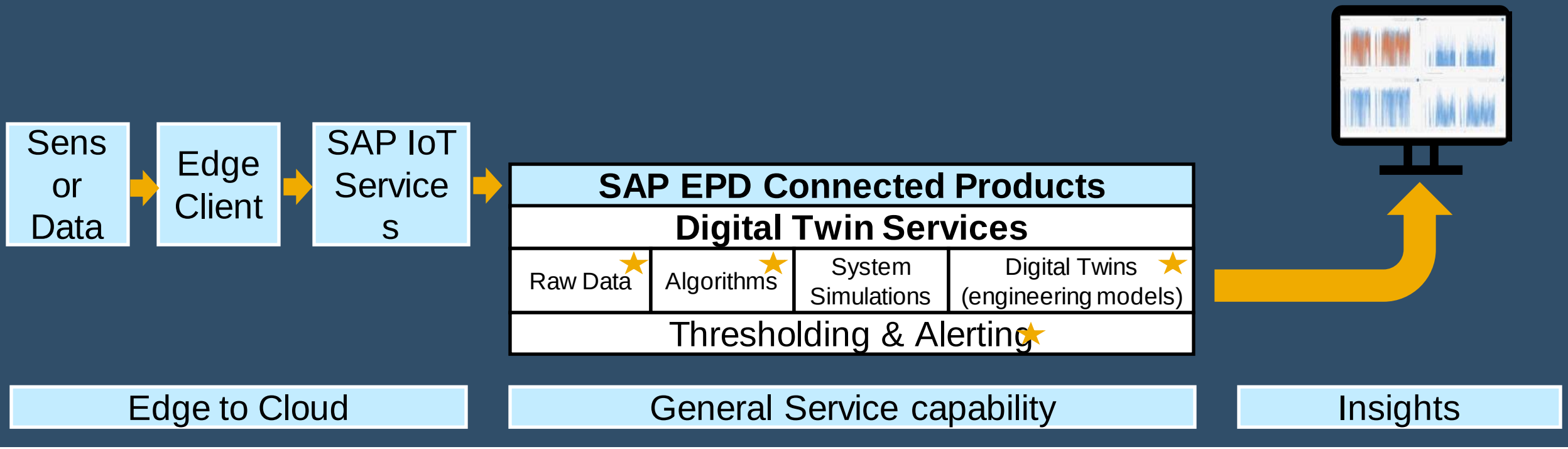
Historic data stored as needed

Global to Local level of Focus – Sub structuring



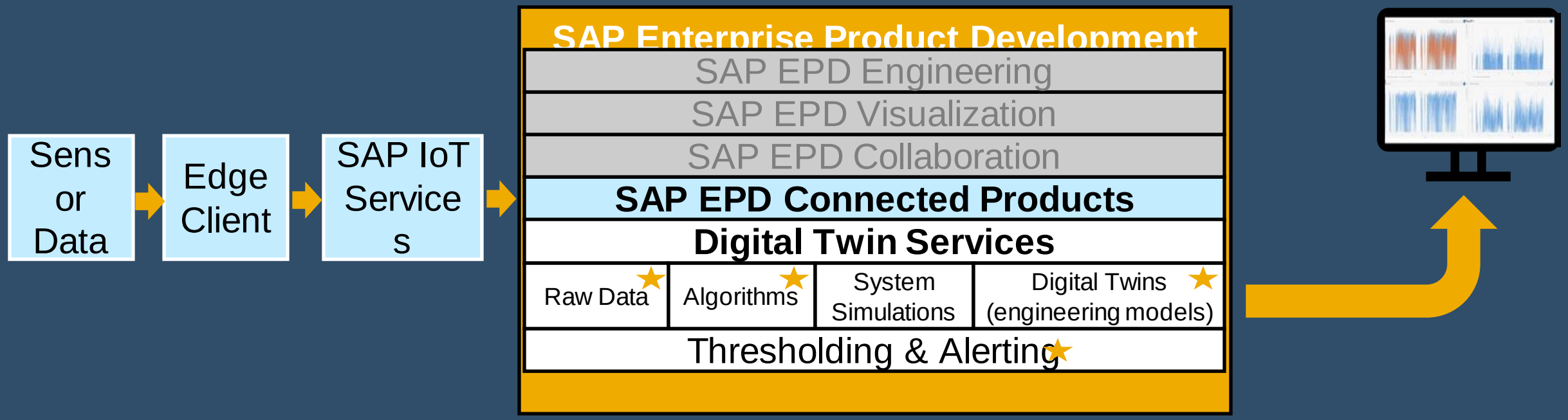


Structural Monitoring



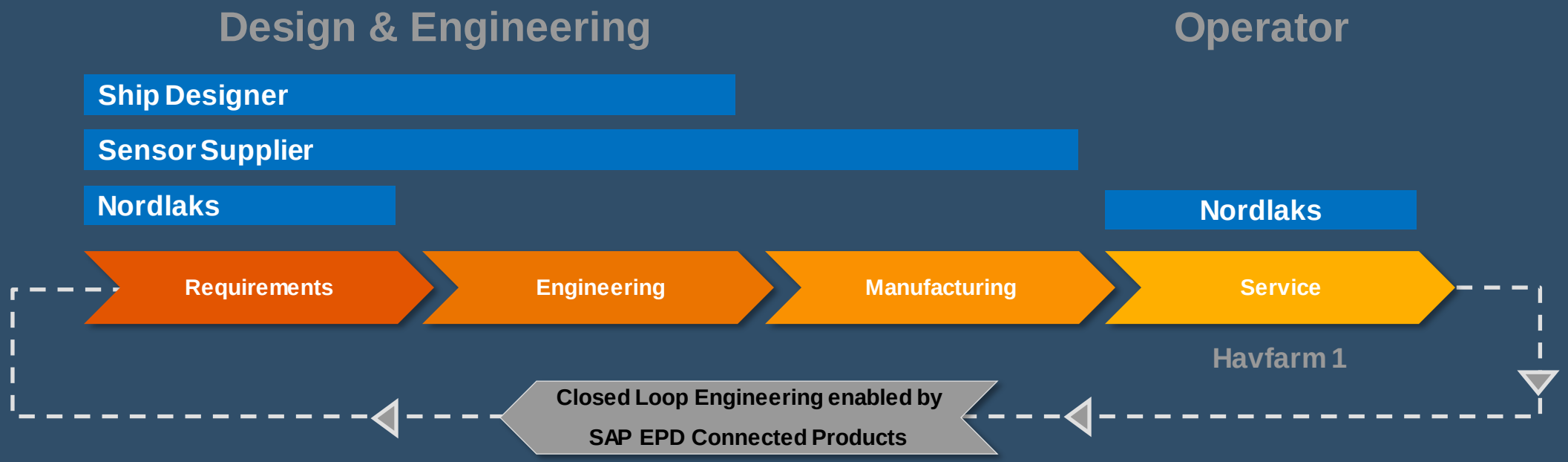
Sensor data Flow

- The onboard sensor data sent to Edge Client (Central hub for data reception, all data to be sent to cloud on same format)
- Data enters Cloud via SAP IoT Services
- Then made available to SAP EPD Connected Products for further Processing
- Raw and processed data is stored and made available through an online User Interface.



The bigger Picture

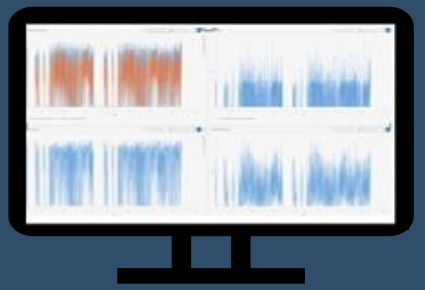
- SAP Enterprise Product Development



Stakeholders & Benefits from *Closed Loop Engineering*

- Operator/Owner: **Nordlaks** — Improved Operations and Maintenance
- Ship Designer — Verification of Design Basis and improvement on Next Generation
- Sensor supplier — Product Improvement, Access to new Business Areas
- Software solution provider: **SAP**

What happends right now?	Real Time monitoring of Key indicators	**React or Optimize**
What happened in the past?	Get access to Historic Data	**Evaluate, Maintain or Share**
What will happen next time?	Gain insights	**Plan**

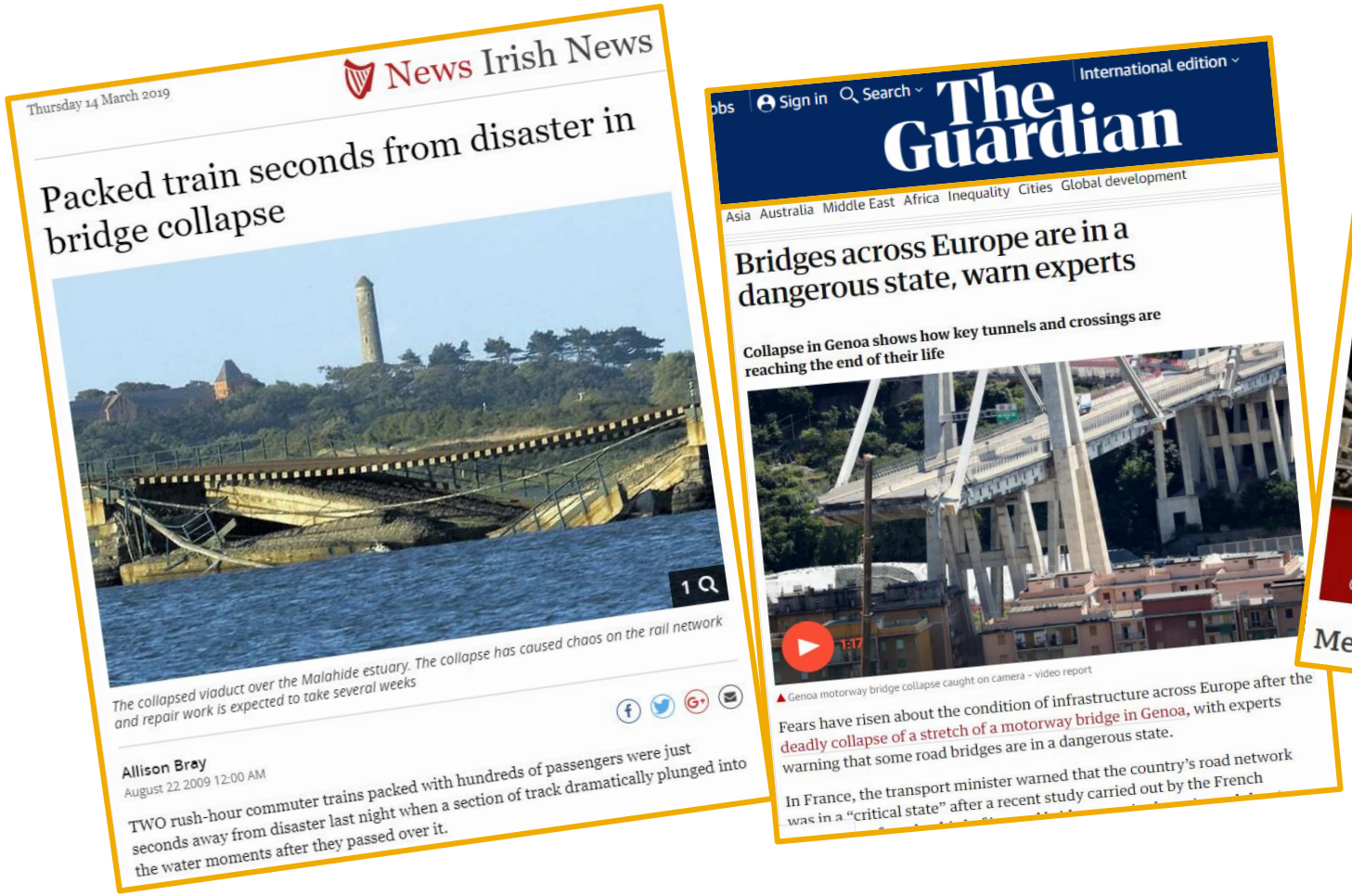


Enablements in a Nutshell

A monitoring system may have many benefits:

- Operational Support
- Alerting if some aspects needs special attention
- Focusing maintenance to areas that need it the most
- Maintenance at the right time (when needed)
- Share data with other stakeholders

Bridge Monitoring
for Norwegian Public Roads Administration



BRIDGE MONITORING

In the U.S. alone, more than 54,000 of the over 600,000 bridges are rated "structurally deficient." There are several factors that cause bridge deterioration, but for reinforced-concrete structures, the primary causes are corrosion and increased loads.

Stavå bridge

Setting the scene

Traditionally the Norwegian Public Roads Administration (NPRA) have based their maintenance on **time scheduled inspections.**

With increasing needs for maintenance NPRA need to address which bridges to **maintain in a more efficient and optimized way.**

NPRA and SAP are collaborating on a **real time monitoring system** for Stavå bridge. The aim is to understand how real time monitoring can be **used to improve todays traditional methods**.

Tasks and responsibilities

PRINT

The Norwegian Public Roads Administration (NPRA) intends to lead the way in the development of an efficient, safe, comprehensive and coherent transport system adapted to tomorrow's needs and technology.

Installation

Battery package on rail

Wireless transfer to gateway

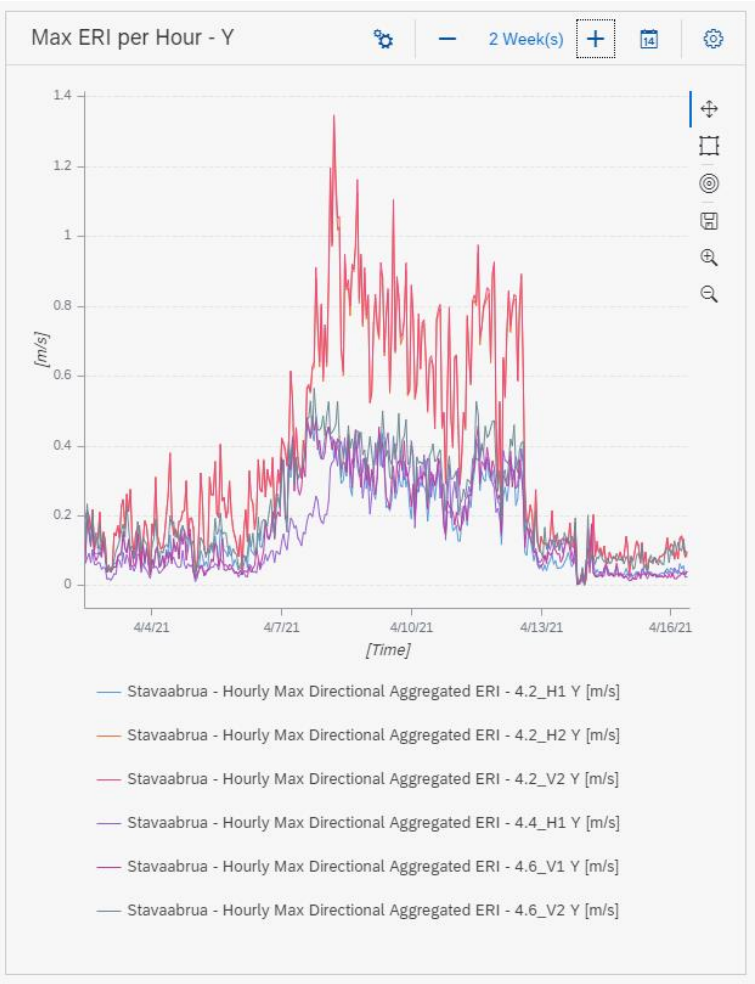
20 3 axis wireless **accelerometers** sampling at 64Hz

8 displacement sensors on cracks and between landfall and bridge deck

Aux data from **temperature readings**, sampling every 10 minutes

Recent insights from Stavå

07/4-21: Sudden increase in KPI's



13/4-21: Inspection

14/4-21: Interrim bridge in place

Wrap up

- Real-time monitoring and EPD CP **reveals incidents at earlier stages** compared to traditional inspection methods
- The Stavå bridge insights with KPI's is **directly applicable to other bridges world wide**
- Important to have **domain expertise** at hand, both IoT understanding and domain insights

Thank You!

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